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# Smoke over the rainforest –
## how fires in the Amazon region contribute to climate change

**In August 2019, several Brazilian states declared a state of emergency. The worst forest fires ravaged the Amazon region in years. Thousands of fires blazed simultaneously and produced so much smoke that the sky above the distant metropolis of São Paulo became dark in the afternoon and massive quantities of soot turned the rain black.**

The images and media reports of the burning **Amazon rainforest** that went around the world in the summer of 2019 provoked international anger and protests. "Fires are nothing new in this region", says Christopher Pöhlker, research group leader at the Max Planck Institute for Chemistry in Mainz. "There are fires in the Amazon every year. But the fires usually fly under the radar of global public". However, the situation was particularly dramatic in August 2019. The Brazilian Institute for Space Research (INPE) recorded more than 45,000 fires in satellite images of the region. This was about two-thirds more fires than were recorded at the same time in previous years. Most of the fires had broken out on private land and near rural settlements. However, nature reserves and indigenous lands were also ablaze. The cause was not an unusual drought. Most of the fires were set deliberately. **Brazil**, where most of the Amazon rainforest is located, has the highest absolute rate of deforestation in the world. Because arable land and pastures are more lucrative than the original rainforest in the short term, small-scale farmers, large landowners, and speculators frequently set fires in order to illegally gain new land for agriculture and claim it for themselves through **slash-and-burn clearing.** The state authorities often tolerate this land grabbing. In August 2019, farmers even called for a "Day of Fire" in order to set large areas on fire together.

Christopher and his team at the Max Planck Institute for Chemistry in Mainz want to find out how the fires influence the climate and rainfall in the region. The chemist and his colleagues are working on this in a unique Brazilian-German joint project: the Amazon Tall Tower Observatory or ATTO for short **(Fig. A)**. The observatory consists of three towers located about 150 km northeast of the city of Manaus in the middle of the rainforest. The towers are equipped with highly sensitive measuring instruments. The highest of these towers is 325 metres tall – taller than the Eiffel Tower. With the ATTO, researchers can obtain data on rainforest meteorology, ecology and greenhouse gases as well as **aerosols**, the various particles contained in the atmosphere. This enables them to study cloud properties and precipitation patterns, linking them to the occurrence of forest fires.

### CLEARING FORESTS FOR CROPLAND AND LIVESTOCK FARMING

The Amazon rainforest currently covers about 5.5 million km$^2$, thus making it the largest rainforest area on earth. To compare: the land

**Fig. A: Research at lofty heights**

The Amazon Tall Tower Observatory (ATTO) towers far above the rainforest's leaf canopy.



**Fig. B: Soy monocultures**

Soybean fields as far as the eye can see. Where lush, biodiverse rainforest once stood, sprawling monocultures now grow. This farm in the Brazilian state of Mato Grosso is currently bringing in the harvest. Most of it ends up as animal feed for factory farms. Germany is an important customer.



areas of Germany and France together cover about 1 million km$^2$. The Amazon region is not only a hotspot of biodiversity and home to 385 indigenous peoples, but also to the world's largest fresh water reservoir. It therefore plays a key role in climatic events. In recent decades, however, the Amazon region has become a hostage to economic interests and is coming under increasing pressure. One fifth of the Amazon rainforest has already been destroyed. The main drivers of deforestation are **cattle breeding and soybean cultivation**. In addition to a population of around 210 million people, Brazil is currently home to around 215 million cattle (as of 2019). This makes Brazil one of the world's leading beef producers. More than one third of Brazil's beef cattle live in the Amazon region. Even more lucrative than cattle breeding is soybean cultivation, which, thanks to state support, has developed into a highly technical branch of the Brazilian economy (Fig. B). Brazil's soy plantations currently cover around 320,000 km$^2$ – an area almost as large as Germany. Around two thirds of Brazil's soy plants grow in the Amazon region. The protein-rich soybeans are mainly used as animal feed and are the basis for the rapidly growing intensive livestock farming in industrialized countries. The EU is one of the major purchasers of these soybeans. Within Europe, Germany is the top buyer. The destruction of the Amazon rainforest often follows the same pattern: first, the valuable trees are cut down. Cattle breeders then set fires to create grazing land. However, cattle farming is profitable only in the short term because the soil is very poor in nutrients. The land will soon be bought up and used to cultivate (predominantly genetically-modified) soybeans. This entails the excessive use of fertilisers and pesticides. The cattle breeders then move on to burn down new areas. Thus, huge pastures and gigantic soy monocultures are eating their way ever deeper into the forest areas.

## CLIMATE BUFFER ON THE ROCKS

This cycle of destruction means not only the loss of an irreplaceable habitat – it also brings with it the risk that the Earth's climate will be thrown out of balance. Because of its size alone, the Amazon rainforest plays an important role in the global carbon cycle (see Geomax 22): its biomass binds the same amount of carbon as the entire human race emits within a decade. Burning down vegetation destroys important carbon reservoirs and releases huge amounts of carbon dioxide, which leads to further climate change. In the worst-case scenario, the forest could eventually lose its buffering effect and begin to release even more carbon dioxide than it absorbs – with devastating consequences for the global climate. In order to limit global warming to below 2°C or even below 1.5°C as stipulated in the Paris Agreement of 2015, deforestation in the Amazon and other parts of the world must be drastically reduced. If this doesn't happen, more frequent extreme weather events (e.g. droughts and storms) are likely to increase tree mortality – and promote fires. The rising temperatures alone would be fatal. Experts assume that the rainforests can survive a temperature increase of only a few degrees Celsius.

## FLYING RIVERS

For rainforests to flourish, both temperature and precipitation are crucial. A single large tree can transpire (i.e. give off water vapour) (i.e. transpire) several hundred litres of water per day. The multi-layered foliage of a rainforest, which reaches up to 40 metres in height, offers eight to 10 times as much potential evaporation surface on 1 m2 of rainforest soil as a piece of pasture land of the same size. Because of the high transpiration rate, the vegetation creates the basis for its own existence. It is only because a forest exists in the first place that enough rain can fall and allow that same forest to grow. About half of the water transpired rains down in the immediate vicinity. Another part of the water transpired feeds the **"flying rivers"** – humid air currents that drift towards the Andes. From there, they are diverted to the south of the continent, where they provide rain. If the forest is lost, the flying rivers come to a standstill, and large parts of South America will gradually become drier.

"If the rainfall over the rainforest is too low, there is a danger that the dense and humid rainforest will die off and turn into more open, savannah-like forests", explains Pöhlker. "There is probably a 'point of no return' – a point at which the system is irreversibly thrown off balance". The Max Planck researchers want to help identify this critical point. To do so, they need to understand how shrinking rainforests, hydrologic balance (i.e. a specific area's inflow, outflow and storage of water), and climate are interlinked and how they influence each other.

## MEASURING STATION ABOVE THE LEAF CANOPY

The ATTO observatory, which is co-financed by the German Federal Ministry of Education and Research (BMBF), offers ideal conditions for this. "The project is unique because it does not simply provide a snapshot of the situation but rather is designed to last several decades", says Pöhlker. "This keeps our finger on the pulse of what is happening and allows us to monitor how the system changes". The researchers from Mainz are collaborating with colleagues from the Max Planck Institute for Biogeochemistry in Jena as well as with Brazilian scientists to study the point at which aerosols, clouds, and climate meet and interact. "We observe the formation and evolution of clouds in order to better understand this complicated and dynamic process".

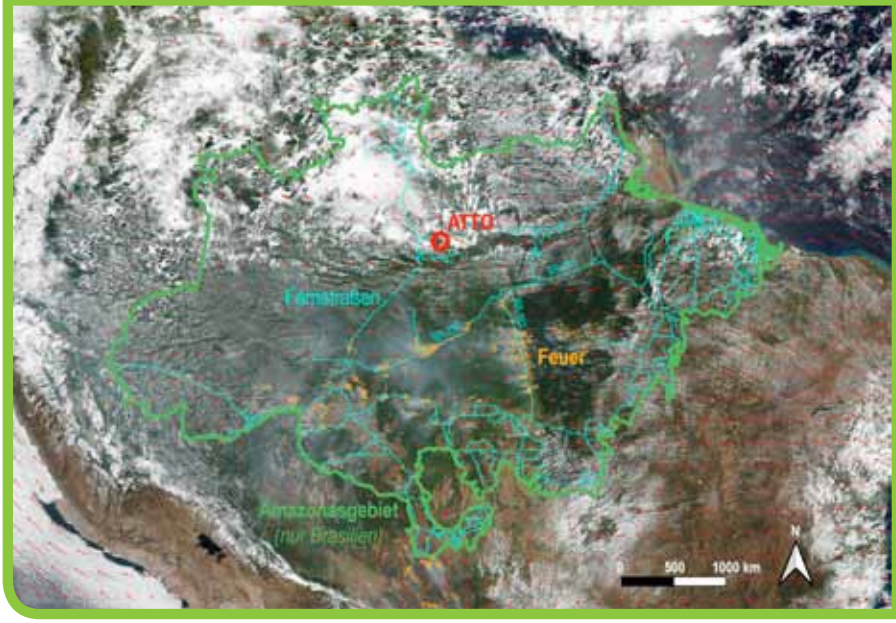
With the help of the ATTO, Pöhlker and his colleagues are investigating cloud formation under various conditions. High above the leaf canopy, air masses moving in from different areas of the country flow around the measuring instruments. With the help of sophisticated computer models, the origin of these air masses can be determined. The researchers can thus directly investigate how clean air compares with air from forest fire areas and how these two types of air affect cloud formation and the microphysical properties of clouds **(Fig. C)**.

The aerosols (microscopic particles) suspended in the atmosphere play a decisive role here. These particles act as condensation nuclei upon which water vapour from the air is deposited as droplets. "For cloud formation, it makes a big difference whether the air is clean or contains a lot of aerosols – like those released by large fires", says Pöhlker.

The decisive factor is the following mechanism: in clean air, water vapour condenses on relatively few aerosol particles (a few hundred per cm3) to form a few large drops. Through **coalescence** – the collision and merging and thus the growth of water drops – rain forms soon after the cloud has formed. In dirty air containing many aerosols (a few thousand to ten thousand particles per cm3), many droplets are formed. However, these are much smaller and have a much lower tendency to coalesce. This can delay or even completely suppress the formation of rain.

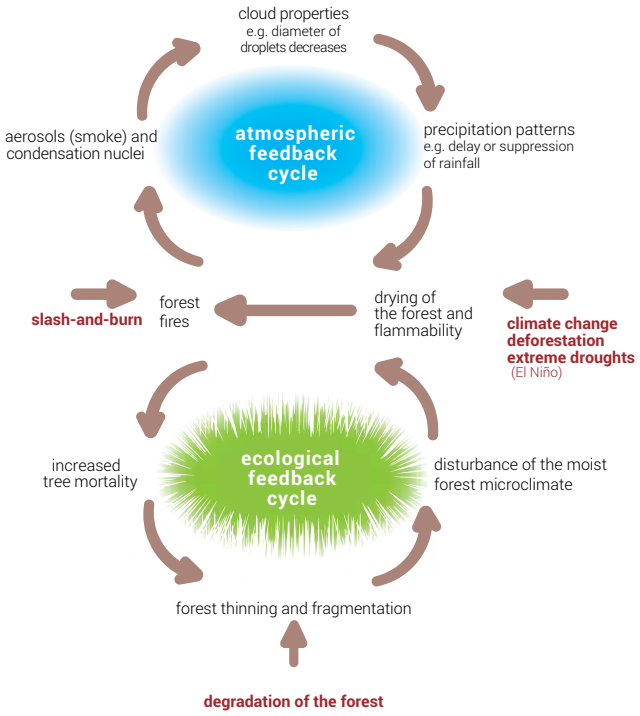
"This mechanism is one of several human-made influences that – according to all we know today – reinforce a tendency toward drying out the rainforest", says Pöhlker. "This, in turn, increases the flammability of the forest and thus the number and intensity of Amazon fires. Because these processes tend to reinforce each other, there is a risk that large-scale developments will be set in motion and that these may soon escalate beyond our control. There are still a number of unanswered questions about exactly how these feedback cycles of fire, smoke, cloud changes and precipitation function. They are a core element of our Amazon research". **(Fig. D)**.

**Fig. C: Satellite image of the Amazon Basin with a fire map for from 12 August 2019**




**There are fires burning in the Amazon region throughout the entire dry season (August to November). The major phase of the Amazon fires was in August 2019. These fires caused great public and political concern worldwide. The map shows fire clusters along the major highways through the Amazon region, especially along the BR-230 (Transamazonica) and BR-163 (Soy Highway). The wind field (red arrows) shows the distribution of the smoke, which was transported over long distances and influenced atmospheric processes throughout the region. The clouds of smoke also regularly reached the ATTO station and caused strong deviations in the atmospheric measurement series.**

## Fig. D: Risky feedback effects




The diagram shows in simplified form self-reinforcing processes (brown arrows). Because of human influence (red), the rainforest is progressively becoming drier and is thus more prone to catching on fire. The feedback effects can lead to developments that we soon may not be able to control.



### THE PUREST AIR ON THE PLANET

One of these unanswered questions involves the search for the state of the atmosphere under the pre-industrial conditions before 1750 – a time before humans released massive quantities of gases and particles from industry, transport, and intensive agriculture into the atmosphere. "We know very little about how many of the atmospheric processes functioned in the pre-industrial age. This is because our current atmosphere is so heavily modified by emissions", explains Pöhlker. "Nowadays, there are also very few places on the planet that can be compared with the pre-industrial era and which allow conclusions to be drawn. During the rainy season (which lasts at least a few weeks a year), the Amazon rainforest is one of those places where the atmosphere is so clean that hardly any human influence can be measured". This extremely clean condition contrasts with the massive pollution caused by the many deforestation fires started during the dry season. By directly comparing the condition of the almost pre-industrial rainy season atmosphere with the heavily polluted dry season atmosphere, researchers can draw conclusions about how essential parts of the world's climate system – especially clouds – react to the many different types of human interference.

New research findings are increasingly showing how complex the interactions between the forest, the atmosphere, and the climate are and what a central role the Amazon rainforest plays in regional and global climatic events. It is therefore all the more important that intact forested areas be protected. However, there is currently no improvement in sight. If anything, the situation is becoming worse. Brazil's President Jair Bolsonaro is closely linked to the agricultural lobby and plans to push ahead with the economic exploitation of the Amazon basin. He also wants to hand over protected areas for this purpose. Under his government, deforestation has increased dramatically. Nevertheless, Pöhlker does not believe that the South Americans alone are responsible for the destruction. "It's all too easy to point fingers and blame Brazil for the disgraceful situation. Just like the fight against climate change and the adoption of more considerate and sustainable policies within the global economic system, the protection of the Amazon rainforest is a collective task that must be accomplished at the international level. It requires the cooperation of everyone". The excessive consumption of meat worldwide is part of the problem. According to the Max Planck researcher, the deforestation in the Amazon can be stopped only by means of economic incentives. "It must become financially worthwhile for Brazil to leave the rainforest standing".


### Keywords

aerosol, Amazon rainforest, Brazil, carbon cycle, cattle breeding, climate, coalescence, flying rivers, land grabbing, slash-and-burn, soy bean cultivation


### Additional Reading

- *Thomas Fatheuer: Amazonien heute – Eine Region zwischen Entwicklung, Zerstörung und Klimaschutz. Band 46 der Schriftenreihe Ökologie, Heinrich-Böll-Stiftung (2019)*
  www.mpg.de/g241 > pdf
- *Spektrum Kompakt: Fire - when forests burn (in German)*
  www.mpg.de/g242

### Link-Tipps

- *ATTO-Projekt (in English)*
  www.mpg.de/g243 >
- *Global Forest Watch (in English)*
  www.mpg.de/g244

### Video-Tipps

- *Forest fires in the Amazon rainforest (in German)*
  www.mpg.de/g245 > YouTube
- *Brazil: The Amazon Highway (in German)*
  www.mpg.de/g246 > YouTube

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